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THE WAVERLY FORMATIONS OF EAST-CENTRAL KENTUCKY[1]

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AND
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During a part of the summer just closed, the authors of this paper were engaged in working out the sub-Carboniferous stratigraphy of East-Central Kentucky for the state survey. The area covered extends from the Ohio River at Vanceburg southwestward seventy miles to the Kentucky River at Irvine. The results obtained, especially in the lower Waverly, are of sufficient interest, it is thought, to warrant publication.

The term Waverly was first applied to a series of rocks in Ohio. Under it are now included all of the rocks from the top of the Ohio shale to the base of the sub-Carboniferous limestone. In central Ohio the series has been divided into six formations, based upon their lithological characters. These formation names will be used, as far as possible, in the Kentucky field. They are, in descending order:

6. Logan formation.
5. Black Hand formation.
4. Cuyahoga formation.
3. Sunbury shale.
2. Berea grit.
1. Bedford formation.[2]

In the southern part of Ohio, however, the conglomerate phase of the Black Hand is not developed as it is in the central part. This makes the division of the upper Waverly into the Black Hand and

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[1] Published by permission of Professor Charles J. Norwood, director of the Kentucky Geological Survey. Presented at the eighteenth meeting of the Ohio Academy of Science, Granville, November 28, 1908.

[2] C. S. Prosser, "The Classification of the Waverly Series of Central Ohio," *Jour. Geol.*, Vol. IX, pp. 214, 215, 1901. That the line of division between the Carboniferous and Devonian systems is still in doubt may be seen by referring to Professor Prosser's paper, "Revised Nomenclature of the Ohio Geological Formations," *Geol. Surv. Ohio, Bull. 7*, pp. 2, 17–21, 1905.

Logan practically impossible since the rocks, beginning with the upper Cuyahoga, are lithologically very similar. This is true also of the Kentucky field.

The lower formations, the Bedford, Berea, and Sunbury, and also the lower part of the Cuyahoga, on the contrary, are quite constant in this part of the state. They have been traced as far south as the Ohio River. Professor Prosser in the preparation of his paper on "The Sunbury Shale of Ohio" pushed the line just across the river and made a section at Vanceburg, Ky.[1]

Shortly after leaving the Ohio River, however, the Bedford and Berea rapidly thin out, allowing the Sunbury shale to rest almost directly upon the Ohio shale. The sandstones of these lower formations also disappear and are replaced by shales. There is also a marked westward thinning.

The discovery of these facts has contributed materially to the correct determination of the Waverly formations of eastern Kentucky. The presentation of these data together with their bearing upon the stratigraphy will form the chief part of this paper. This, probably, can best be accomplished by giving in order a few sections which clearly show the changes.

At the southeastern end of Vanceburg is a high hill known as Alum Rock. Along a path ascending this hill the rocks are nicely exposed from the Ohio shale to the lower part of the Cuyahoga. Since this section is one of the most typical of the lower Waverly in Kentucky, it will be given somewhat in detail, although it has already been published.[2]

SECTION OF ALUM ROCK, VANCEBURG

	Feet	Inches	Feet
5. *Cuyahoga formation*			39
Interval covered except a thick layer of argillaceous sandstone at the top. The sandstone contains *Taonurus*. Small phosphatic nodules are found in the basal part of the interval.			
4. *Sunbury shale*, total thickness			15½
Black, fissile, carbonaceous shales, which cannot be distinguished, lithologically, from the Ohio shale.			

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[1] *Jour. Geol.*, Vol. X, pp. 292, 293, 1902.

[2] *Loc. cit.*

3. *Berea grit*, total thickness			22¼
Thick layer of gray sandstone	2	6	
Heavy layer of rather coarse-grained gray sandstone, the upper surface excellently ripple-marked	3		
Medium to thick-bedded rather coarse-grained gray sandstones, beautifully ripple-marked	15		
Arenaceous shales	1		
Layer of fairly coarse-grained gray sandstone		9	
2. *Bedford formation*, total thickness			95⅚
Blue arenaceous shales and shaly sandstones. Lower part slightly covered	35		
Arenaceous shales with thin sandstone partings	7		
Layer of thick-bedded gray sandstone	1	8	
Arenaceous shales with two layers of sandstone	6	9	
Heavy layer of gray sandstone, with lower surface contorted	2	4	
Arenaceous shales with two layers of gray sandstone	6	6	
Layer of thick-bedded buff sandstone	1	9	
Medium-bedded gray sandstones with shaly partings	2	10	
Arenaceous pink shales with sandstone partings	2	6	
Covered interval	5		
Layer of thick-bedded, buff sandstone	2		
Practically covered interval with some argillaceous shales.	22	6	
1. *Ohio shale*			242
Black fissile, carbonaceous shales. About ten feet from the top, one or two linguloid shells occur. Near the central part the shales become softer and lighter in color and resemble a similar zone in the Ohio at Columbus, (Ohio). The interval (242′) is mostly exposed and extends to the level of the Chesapeake and Ohio Railroad. At "Slate Point," however, the top and bottom contacts are shown and the total thickness is 301¼ feet.			

The most striking feature of this section is the development of sandstones within the Bedford formation, which usually consists of shales alone. This feature recalls a similar development in northern Ohio. Along Euclid Creek, east of Cleveland, sandstones occur in quite regular layers at about the same horizon, and are extensively quarried. They are known to the trade as the Euclid stone and the division has been appropriately named the "Euclid lentil" by Professor Prosser.[1]

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[1] Used in a manuscript not yet published.

Alum Rock hill extends only a short distance, 39 feet, above the Sunbury shale and this interval is practically covered except at the top where a massive layer of sandstone is exposed. Higher strata are found, however, in an adjacent hill known as "Slate Point." Near the summit the lower Cuyahoga is quite well exposed along the road which ascends the hill. It consist of even-bedded argillaceous sandstones or freestones with shaly partings and is the typical Buena Vista member.[1]

On the Petersville Road some three miles south of Vanceburg is a long hill known as the Vanceburg hill. After this is crossed, the Sunbury shale is found at its base, and below, 19½ feet of the top of the Berea grit. Instead of being a massive sandstone, as at Alum Rock, the most of this interval is composed of arenaceous shales and shaly sandstones, only 2½ feet reaching the proportions of a thin-bedded sandstone. The upper two feet have been considerably disturbed while the last layer varying from 0 to 9 inches is badly contorted. There was no question as to this identification, however, as the sandstones were excellently ripple-marked and were directly overlain by the complete Sunbury.

Such marked lithological changes in so short a distance are very striking and should cause subsequent study to be performed more critically. They also prepare us for, or cause us to anticipate, other changes.

At various places along the next six or eight miles of this same road, slight exposures show that the area has been somewhat disturbed. This is mostly in the form of folds and affects the top of the Ohio shale and the Bedford and Berea. In one place the movement was sufficient to cause a fault but the exposure was not large enough to show the amount of displacement.

Thirteen miles south of Vanceburg, at the home of J. E. Kegley, the Petersville Road crosses a small run called Elk Lick. At the road side south of this stream is a steep hill, upon the side of which the Ohio, Berea, and Sunbury are exposed. While the out-crops are not all that could be desired, yet they show that the Bedford and

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[1] For the revival and present usage of the term "Buena Vista" and another, "City ledge," to be used later, the reader is referred to pages 341 and 342 of Professor Prosser's paper on "The Waverly Formations of Central Ohio," *Am. Geol.*, Vol. XXXIV, 1904.

Berea have thinned from 118 feet to a total not exceeding 75 feet in this distance.

ELK LICK CREEK SECTION

	Feet	Inches	Feet
4. *Sunbury shale.*			
Pieces of black, fissile, carbonaceous shale directly above the sandstone layers.			
3. *Berea grit*			75
2. *Bedford formation*			
Medium-bedded sandstones, ripple-marked on the upper surfaces. Unquestionably Berea	7	6	
Covered interval, which probably contains the contact of the Bedford and Berea	67	6	
1. *Ohio shale*			30
Black, fissile, carbonaceous shales, which extend down to the level of the highway at the spring.			

In the second gully west of the schoolhouse in Petersville, the strata are exposed more or less completely from the Ohio shale to the lower Cuyahoga formation. By combining the exposures of both branches of this gully, an almost continuous section is had from the top of the Ohio to the top of the Sunbury. This is the key section to the lower Waverly problem. The Bedford and Berea cannot have a total thickness of over 46½ feet, showing a thinning of over 70 feet in 18 miles or nearly 30 feet in 5 miles. The sandstones, too, have also practically disappeared, leaving only the shales behind. Whether these belong to the Bedford alone or to the Bedford and Berea is still an open question as both formations contain sandstones at Vanceburg. If a section of about normal Berea, underlain by shales only, were obtainable somewhere in the vicinity of Elk Lick, then these 46½ feet could be referred to the Bedford. However, such a section has not been and probably never will be found. The shales probably belong in part to the Bedford and in part to the Berea. If this be true they cannot be separated into the two formations from here southward and for the present, at least, they will be designated together under the inclusive term Bedford-Berea.

PETERSVILLE SECTION

	Feet	Inches	Feet
4. *Cuyahoga formation*			55½
Medium to heavy-bedded, gray, argillaceous sandstones with shaly partings	14		
Covered interval	41	6	

3. *Sunbury shale*, total thickness			$12\frac{1}{2}$
Black, fissile, carbonaceous shales.			
2. *Bedford-Berea*, total thickness			$46\frac{5}{12}$
Covered, except some arenaceous and calcareous shales, which are probably ripple-marked	14		
Bluish to buff arenaceous shales with an occasional parting, ripple-marked	17	6	
Blue, argillaceous to arenaceous shales with an occasional calcareous or arenaceous parting	7		
Thin layer of sandstone		5	
Blue, argillaceous shales with a little black, carbonaceous shale at the base	4	3	
Covered interval	2	6	
Soft, argillaceous shales mixed with some black shales		9	
1. *Ohio shale*			85
Black, carbonaceous shales, slightly covered	85		
Covered, to the water level of Kinniconick Creek at the church	10		

Near Fox Springs, Fleming County, an exposure shows a probable thickness of $32\frac{1}{2}$ feet for the Bedford-Berea. While the horizon continues to thin to the southward, the rate of decline is much more gradual than it has been in the area just discussed, and for this reason sections will now be given at longer intervals only.

In the highway leading up the hill at Rockville Station, Rowan County, is an excellent exposure from the Ohio shale to the lower Cuyahoga. The Bedford-Berea is only $18\frac{1}{2}$ feet thick, but probably the greatest value of the section is its aid in determining the true horizon of the sandstones quarried in this vicinity. These have been referred to the Berea grit by Hoeing,[1] but a glance at the following section will show that they belong to the Buena Vista member of the Cuyahoga formation. The Buena Vista sandstones with shaly partings are typically developed but the interval is only 37 feet as compared with 60 feet for the same member along the Ohio River west of Portsmouth, Ohio.

SECTION AT ROCKVILLE STATION

	Feet	Inches	Feet
Soil to the level of the peneplain	15		
4. *Cuyahoga formation*			90
Soft, blue, argillaceous shales with an occasional ferrugi-			

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[5] *Kentucky Geol. Surv., Bull. I*, p. 49.

	Feet	Inches	Feet
nous parting. The lower two feet covered, but probably shales	35		
Soft, blue, argillaceous shales alternating with thin to medium-bedded argillaceous sandstones, the shales predominating	18		
Top of the Buena Vista member and also the top of the stone quarried. Even-bedded argillaceous sandstones, "freestones," with thin partings of blue argillaceous shales. The sandstones contain *Taonurus*. The layers are mostly medium-bedded, that is of proper thickness for commercial use. Their size together with the shaly partings render them easily quarried. They are quite extensively worked and make a beautiful and excellent stone	25	6	
Soft, blue, argillaceous shales with three or four shaly sandstone partings, which contain *Taonurus*	4	6	
Soft, blue argillaceous shales	7		
3. *Sunbury shale*, total thickness			16¼
Black, fissile, carbonaceous shale.			
2. *Bedford-Berea*, total thickness			18½
Soft, blue, argillaceous and finely arenaceous shales, and fine-grained shaly sandstone. The lower two feet have one or two thin layers of black, fissile shale.			
1. *Ohio shale*			20¾
Black, fissile, carbonaceous shales	2		
Covered to the level of the Chesapeake & Ohio Railway Exposures in a nearby gully and the main stream show, however, that all of this interval is Ohio shale	18	9	

Quite a variation in the thickness of the Bedford-Berea occurs along an east-and-west line at Olympian Springs, Bath County. This variation will be given here to prepare us for the remarkable thinning farther southward. Two sections were made within a radius of a mile of the Springs. In the eastern of these the horizon measured 12½ feet, in the western 5¾ feet, while on the opposite side of the hill from the latter and a half mile farther west, the thickness was only 2 inches. The Sunbury on the contrary was quite regular, measuring 12⅓, 12¾, and 12 feet for the respective sections.

From Olympian Springs southwestward, at least on the western border of the Cuyahoga outcrops, the sandstone layers of the Buena Vista member begin to gradually disappear. By the time Jeffersonville, Montgomery County, is reached, only a single layer remains. It occupies the position of the lowest, but whether or not it is one and the same layer or different layers at the various exposures to the southward cannot be determined. From its position in the following section, which was taken one mile east of town, it will be seen to occupy the position of the "City ledge."

SECTION AT SLATE CREEK BRIDGE, JEFFERSONVILLE

	Feet	Inches	Feet
4. *Cuyahoga formation*			$5\frac{1}{12}$
Layer of massive, argillaceous sandstone with *Taonurus* abundant. In this vicinity exposures are sufficient to show seventeen or eighteen feet of argillaceous shales above this layer	2	10	
Soft argillaceous shales	2	3	
3. *Sunbury shale*, total thickness			11
Black, fissile, carbonaceous shales.			
2. *Bedford-Berea*, total thickness			$4\frac{1}{6}$
Bluish to dark, slightly ferruginous, argillaceous shales.			
1. *Ohio shale*			$31\frac{1}{2}$
Black, fissile, carbonaceous shale to the base of the exposure	31	6	
Black shales extend to the level of Slate Creek at the bridge, but these were not measured.			

Still farther south the lower layer finally disappears. In place of the Buena Vista sandstones, soft, argillaceous shales occur in the lower Cuyahoga. To these clayey shales, August F. Foerste applied the term "Linietta clay," provisionally, before their identity with the New Providence shale of southern Indiana was ascertained.[1] The New Providence shale with the overlying Riverside sandstone, it will be recalled, make up the Knobstone formation of Indiana.

About Indian Fields in Clark County, the Ohio shale extends to near the top of the hills. One mile east of the station, along a highway passing within a quarter of a mile of Oil Springs, the following section was taken. The chief interest in this one is, that while the Bedford-Berea is only two inches in thickness, the shales are fossiliferous. More will be said about these fossils after the Irvine section has been given.

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[1] *Kentucky Geol. Surv., Bull. VII*, p. 14.

SECTION AT INDIAN FIELDS

	Feet	Inches	Feet
3. *Sunbury shale*			9¼
Black fissile, carbonaceous shales.			
2. *Bedford-Berea*, total thickness			¼
Fossiliferous, argillaceous, and calcareous shales.			
1. *Ohio shale.*			
Black, fissile, carbonaceous shale extending down the hill for a long distance but not measured.			

An instructive section is seen one mile northwest of Stanton, Powell County, in a lane leading up to the residence of Lewis Foulkner.

SECTION AT STANTON

	Feet	Inches	Feet
4. *Cuyahoga formation*			4¼
Soft, blue, argillaceous shale not measured.			
Layer of buff, fine-grained, calcareous sandstone, which weathers into large flat nodules	1	3	
Soft, blue, argillaceous shale	3		
3. *Sunbury shale*, total thickness			6½
Black, fissile, carbonaceous shale.			
2. *Bedford-Berea*			$\frac{7}{12}$
Bluish, argillaceous, and calcareous shales.			
1. *Ohio shale*			16½
Black, fissile, carbonaceous shale	16	6	
Covered to the highway	19	9	

The final section is from Irvine, Estill County. Here the Bedford-Berea is 1 foot, 6 inches in thickness and fossiliferous, while the Sunbury is only 3 feet. This very gradual decrease in the Sunbury should be noted although it is much less marked than the thinning of the Bedford-Berea.

SECTION OF MINERVA MOUNTAIN, IRVINE

	Feet	Inches	Feet
6. *Sub-Carboniferous limestone*			1
Yellowish, sandy-like limestone, lying at the extreme top of the hill.			
5. *Upper Waverly series*, not divided			344
Covered interval	60	6	
Thin bedded, buff, argillaceous sandstones, which weather to thin shaly pieces, *Taonurus*	17		
Layers of massive, buff, argillaceous sandstone, *Taonurus* abundant	24		

Buff, argillaceous sandstones, weathering to shales. *Taonurus*	17		
Covered interval	225	6	
4. *Cuyahoga formation*, top not determined			144
Brownish, ferruginous, and calcareous, nodular layer of sandstone		6	
Indurated, bluish to pinkish, argillaceous shales with ferruginous, nodular layers	69	6	
Soft, bluish, argillaceous shale with ferruginous, nodular layers, slightly covered (top of Linietta clay)	63	6	
Layer of brownish, argillaceous sandstone, which breaks up into shaly layers	2		
Soft, bluish to pinkish, argillaceous shales with small phosphatic nodules	8	6	
3. *Sunbury shale*, total thickness			3
Black, fissile, carbonaceous shales.			
2. *Bedford-Berea*, total thickness			1½
Argillaceous shales with phosphatic nodules		2	
Black, fissile, carbonaceous shales		3	
Dark, argillaceous shales, with some carbonaceous material		6	
Gray, calcareous, and argillaceous shales, slightly fossiliferous		2	
Yellowish, calcareous, and argillaceous shales, the upper part very fossiliferous		5	
1. *Ohio shale*			94½
Black, fissile, carbonaceous shales, with an occasional softer argillaceous layer. Practically all exposed to the highway.			

The thinning-out of these formations can probably be more clearly shown graphically. The sections that have just been described are grouped in the two accompanying figures, and follow each other consecutively.

Several of the fossils collected at Irvine and also at Indian Fields when compared with those from the base of the Bedford at Columbus, Ohio, prove to be the same species. Of these *Macrodon hamiltoniae* is the most abundant one common to both fields. This paleontological confirmation of the conclusion reached by a lithological study is surely gratifying.

It may be argued from this that the thin argillaceous horizon should be referred to the base of the Bedford rather than to the Bedford-

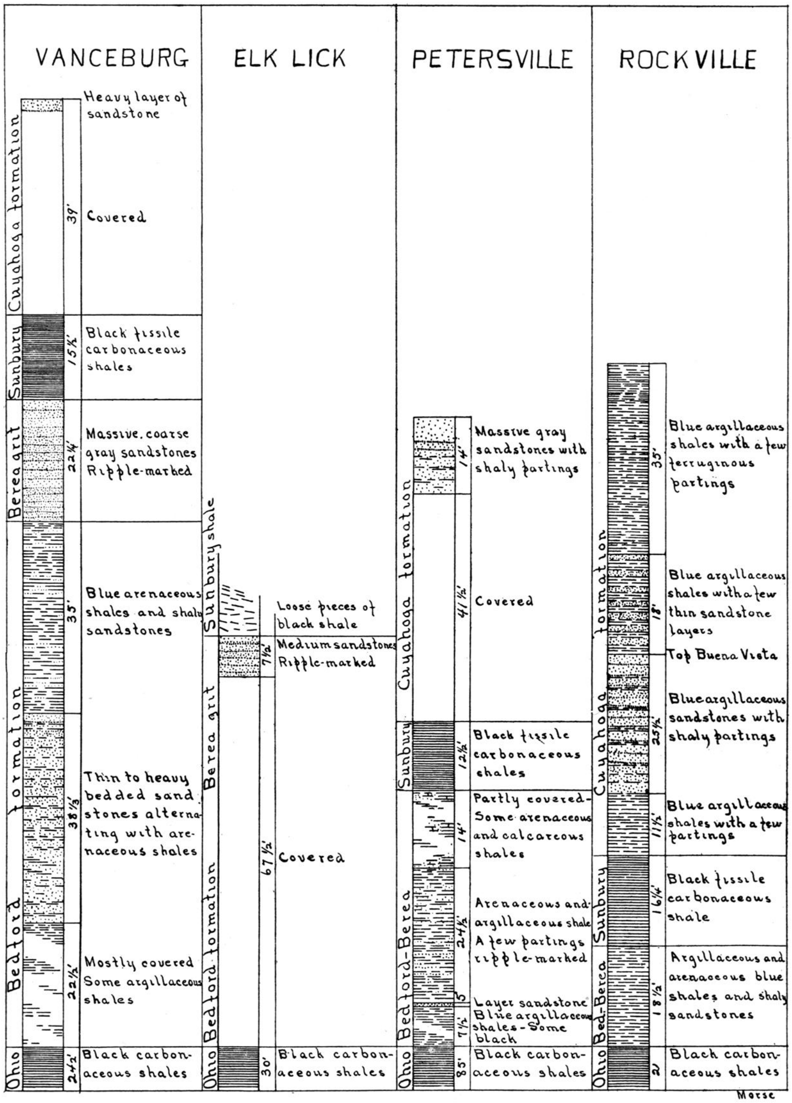
VANCEBURG
ELK LICK
PETERSVILLE
ROCKVILLE
Heavy layer of sandstone
Cuyahoga formation
39'
Covered
Sunbury
15½'
Black fissile carbonaceous shales
Berea grit
22¼'
Massive, coarse gray sandstones Ripple-marked
Bedford formation
35'
Blue arenaceous shales and shaly sandstones
38⅓'
Thin to heavy bedded sandstones alternating with arenaceous shales
22½'
Mostly covered Some argillaceous shales
Ohio
24½'
Black carbonaceous shales
Sunbury shale
Loose pieces of black shale
Berea grit
7½'
Medium sandstones Ripple-marked
Bedford formation
67½'
Covered
Ohio
30'
Black carbonaceous shales
Cuyahoga formation
14'
Massive gray sandstones with shaly partings
41½'
Covered
Sunbury
12½'
Black fissile carbonaceous shales
Bedford-Berea
14'
Partly covered-Some arenaceous and calcareous shales
24½'
Arenaceous and argillaceous shale A few partings ripple-marked
5'
Layer sandstone
7½'
Blue argillaceous shales-Some black
Ohio
85'
Black carbonaceous shales
Cuyahoga formation
35'
Blue argillaceous shales with a few ferruginous partings
18'
Blue argillaceous shales with a few thin sandstone layers
Top Buena Vista
25½'
Blue argillaceous sandstones with shaly partings
11½'
Blue argillaceous shales with a few partings
Sunbury
16¼'
Black fissile carbonaceous shale
Bed-Berea
18½'
Argillaceous and arenaceous blue shales and shaly sandstones
Ohio
2'
Black carbonaceous shales
Morse

FIG. 1

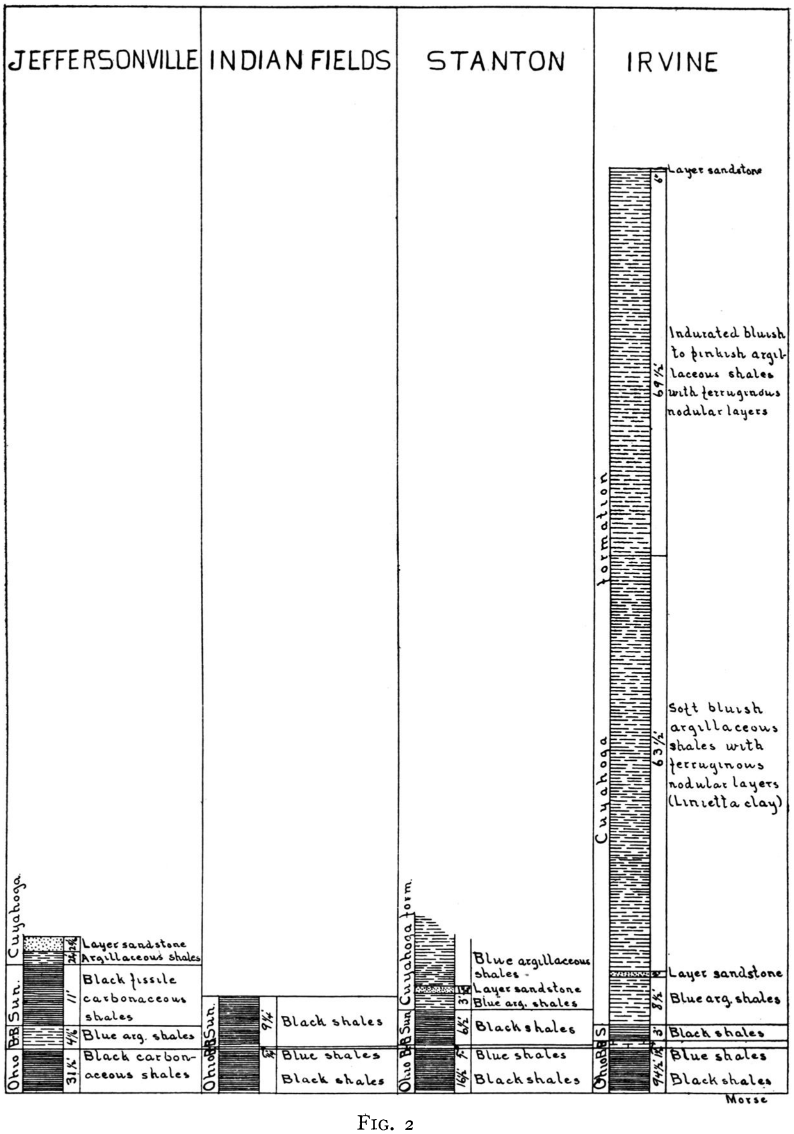
JEFFERSONVILLE
INDIAN FIELDS
STANTON
IRVINE
Cuyahoga.
Sun.
B.B.
Ohio
2½'
2½'
11'
4½'
31½'
Layer sandstone
Argillaceous shales
Black fissile carbonaceous shales
Blue arg. shales
Black carbonaceous shales
Sun.
B.B.
Ohio
9¼'
Black shales
Blue shales
Black shales
Cuyahoga form.
Sun
B.B.
Ohio
3'
6½'
16½'
Blue argillaceous shales -
Layer sandstone
Blue arg. shales
Black shales
Blue shales
Black shales
Cuyahoga formation
S
B.B.
Ohio
6"
69½'
63½'
8½'
3'
94½'
1½'
Layer sandstone
Indurated bluish to pinkish argillaceous shales with ferruginous nodular layers
Soft bluish argillaceous shales with ferruginous nodular layers (Linietta clay)
Layer sandstone
Blue arg. shales
Black shales
Blue shales
Black shales
Morse

FIG. 2

Berea. This is a strong argument, yet from facts set forth above it seems advisable to refer the rapidly decreasing horizon to the Bedford-Berea.

In this connection, it might be well to give the conclusions reached by Professor Williams in his paleontological study of the black shales. He states that an

> examination of the sections at Irvine, Kentucky, the other side of the Cumberland channel revealed the fact that there the black shales were thinner but held on in their purity, well up into Carboniferous time. The intercalations consist of calcareous and ferruginous, concretionary sheets, and carry undoubted Carboniferous fossils and occur in the sections before the black shale loses its characteristic expression.[1]

These black shales have been correlated with the Ohio black shale in the various geological reports of the state. The geologists of the National Survey, approaching the field from the south, have, on the other hand, designated them as the Chattanooga shale.[2] Both have referred them, in their entirety, to the Devonian system. That they belong to both the Devonian and Carboniferous systems has, it is thought, been clearly demonstrated.

Of the London and Richmond Folios of the U. S. Geological Survey, the latter adjoins the Irvine field. In these Campbell has designated the clay shales and argillaceous sandstones, above the Black shale, as the Waverly formation. It is permissible, according to the rules of that survey, to reduce a series to the rank of a formation, but, as applied here, Waverly covers not more than the upper half of that division. The lower half, Bedford, Berea, and Sunbury, has just been shown to be included within the limits of the Chattanooga (Ohio) shale.

It is interesting to note that Professor Grabau anticipated this limitation. Referring to the London Folio, he states that:

> The shale above the Black (Ohio) shale is referred to the Waverly, of which it probably constitutes the upper portion only. As at Irvine, the transition from the Black shale to the overlying beds is probably a gradual one.[3]

This conclusion seems to have been reached deductively, from a study of Professor Williams' paper which he quotes and to which reference was made above.

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[1] *Am. Jour. Sci.*, 4th series, Vol. III, p. 398.

[2] Estillville, London and Richmond Folios, U. S. Geol. Surv.

[3] *Bull. Geol. Soc. Am.*, Vol. XVII, pp. 609, 610.

To summarize, then, it may be stated that: The Bedford and Berea formations thin rapidly southwestward from the Ohio River and this horizon, even after it has been reduced to a thickness of only a few inches, can be traced to near the crossing of the Cincinnati geanticline by the Waverly series.

The Sunbury shale, on the contrary, suffers but little decline, at least until Indian Fields is reached.

The Ohio black shale of the Kentucky reports or the Chattanooga shale of U. S. reports, south of Petersville, is not of Devonian age alone but of Devonian and Carboniferous, that is, is composed of both the Ohio and Sunbury shales, and a thin zone representing the Bedford and Berea.

The sandstones, which are extensively quarried about Rockville Station belong to the Buena Vista member of the Cuyahoga formation rather than to the Berea grit.

The Buena Vista sandstones begin to disappear from Olympian Springs southwestward except a single layer which, if not always the same, at least occupied the position of the lowest and which persists as far south as Stanton if not to Irvine.

The Linietta clays belong to the lower part of the Cuyahoga formation.

The so-called Waverly of at least the Richmond Folio includes only the upper part of the Waverly, beginning with the base of the Cuyahoga.